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EXPERIMENTAL STUDY OF FIBER REINFORCED CONCRETE USING METALLIC AND NON-METALLIC FIBERS

Shah Newaz Aftab[1], Chaiti Karmakar[2], Hasan Mohammod Zakaria[3] and Sristi Das Gupta*[4]

[1,]Department of Civil Engineering, Ahsanullah University of Science and Technology, Bangladesh,e-mail:chayonshah15091@gmail.com
[2]Department of Civil Engineering, Ahsanullah University of Science and Technology, Bangladesh, e-mail:chaitykarmakar15094@gmail.com
[3]Department of Civil Engineering, Ahsanullah University of Science and Technology, Bangladesh, e-mail: zakariaorko@gmail.com
[4]Faculty of Civil Engineering, Ahsanullah University of Science and Technology, Bangladesh, e-mail: payelcuet@gmail.com

***Corresponding Author**

ABSTRACT

Concrete is a brittle material with strong compressive strength but with little tensile strength (approximately 10% of its compressive strength) having little resistance to cracking.The fragile characteristic of concretecan be overcome by blending the concrete with fibrous material, which is termed as fiber reinforced concrete. Fiber-reinforced concrete (FRC) has become a sustainable material used in various constructions such as building pavements, large industrial floors, and runways. With the modern technology, fibers are two types, such as: artificial fibers and natural fibers. This paper deals with the concept of using metallic (and non-metallic fibers in concrete. In this research, GI (Galvanized Iron) and Jute chopped fibers were used to develop an FRC material to study the possible improvement in the 28-days strength. Clumping of fibers at high fiber amounts caused mixing and casting problems. These problems become even more severe when long fibers are used at the high fiber dosage amount. In this study, different composition of Jute (0.1%, 0.2%, 0.3%) and GI fibers (1%, 1.5% and 2%) with different lengths are added in concrete. A significant increment of compressive and tensile strength between plane concrete and fiber reinforced concretes were found. The aim of this paper is to study the strength characteristics of metallic fiber and non-metallic fiber in concrete and make a comparison with normal plain concrete specimens.

Keywords: *Metallic fiber, Non-metallic fiber, Jute, G.I fiber, Strength.*

1. INTRODUCTION

Concrete is a composite material obtained by permitting a carefully proportioned mixture of cement, sand and gravel or other aggregate and water to harden in forms of the shape and dimensions of the desired structure. The materials are mixed together until a cement paste is developed, filling most of the voids in the aggregates and producing a uniform dense concrete.Concrete is relatively brittle and its tensile strength is relatively low in contrast with thecompressive strength (Sivakumer*et al*., 2007).For the sustainable development with higher strength is the growing demand in construction industry. Concrete reinforcement by natural fibers are more promising to insure the concrete strength improvement with nonhazardous impact on environment as well as the effective use of available natural assets. To achieve this goal, numerous researchers have used the fiber as well as yarn very effectively as a concrete reinforcing material ((Nemati, 2013).

For many applications, it is becoming increasingly popular to reinforce the concrete with small amount of randomly distributed fibers. The concept of using fibers as reinforcement is not new. Research into new fiber-reinforced concretes continues today. Fibers include steel fibers, glass fibers, synthetic fibers and natural fibers - each of which lend varying properties to the concrete. From the light of the structural steel reinforcement contribution to the tensile strength of concrete, steel fibre usage in concrete industry has also been developed recently. Steel fibre reinforced concrete has superior tensile performance with respect to plain concrete depending on the type and amount of steel fibers. In contrast to metallic fiberusing natural fiber in concrete can be a cost effectivesolution for making FRC.

Fiber reinforced concrete (FRC) may be defined as a composite materials made with Portland cement, aggregate, and incorporating discrete discontinuous fibers (Gupta S D *et al.*,2016).Fibers are usually used in concrete to control cracking due to plastic shrinkage and to drying shrinkage. Some types of fibers produce greater impact, abrasion, and shatter resistance in concrete. Their main purpose is to increase the toughness of the materials and also increase the tensile and flexural strengths of concrete, and thus reduce steel reinforcement requirements and control the crack widths tightly.

Among two different types of fibers (natural fibers and artificial polymer-based fibers) natural fibers are promising to use as reinforcement to overcome the inherent deficiencies in FRC reinforced with polymer-based fiber (Parveen*et al*, 2013). The main deficiencies associated with the use of artificial fibers are relatively high cost, health and environmental hazards. On the contrary, natural fibers which are biodegradable, inexpensive, environmentally friendly, and easily available as are produced from naturally available resources, for instance, coconut tree, banana tree, cotton, and jute. Researchers have conducted numerous studies on the effect of natural fibers on the mechanical and physical behavior of concrete to investigate the extent of improvement. In recent years, unrelenting efforts have been observed for using natural fibers in FRC for improving the energy efficiency, economy, and eco-friendliness flavour.

Jute fibers, which come from annual plants, are available in plenty in Bangladesh.These fibres are extracted from the ribbon of the stem. It is a long, soft and shiny vegetable fiber having off-white to brown color. High tensile strength and low extensibility are some key properties of jute fiber. Recent studies have shown that jute fibre delays the hardening of concrete and improves the resistance of concrete against cracking.Nowadays, metallic fibers(galvanized steel) are also used as the fiber reinforcement to boost up the strength of concrete. Galvanized steel wire is made of carbon steel zinc plated. The diameter of the wire generally varies 0.30 mm to 1.2 mm. Specific gravity of the G.I. wires are also ranges between 6000-7500 Kg/m3.

Basically the Conventional concrete is brittle and has poor resistance to crack opening. Numerous liturratures showed that use of Jute fibers and GI fibers in lower strength concretes increase the compressive strength significantly when it is compared to plain un-reinforced matrices and is directly related to volume fraction of fiber used. This study provides in-depth look into the metallic and non-metallic fiber reinforced concrete properties like tensile strength and compressive strength.The effects of two types of fiber (Jute and Steel) reinforcement on concrete is reported in this paper.

2. MATERIALS AND METHODS

2.1 Materials

In this experiment, Ordinary Portland cement (OPC) was used. The percentage of clinker and gypsum in the cement was 95 - 100% and 0-5% respectively. Coarse sand was used as fine aggregate while crushed stone chips was used as coarse aggregate..In this research, jute fiber of 15 mm was used with the proportion of cement, coarse aggregate and sand with the fixed water cement ratio of 0.38. The specimens were prepared for different volumetriccontent of jute fibers, 25mm (0.1%, 0.2%, 0.3%) and curing was done for 28 days. Furthermore for G.I. fiber, 40 mm of length was used with the proportion of (1%, 1.5%, 2%).

Mix design was conducted as per American Concrete Institute (ACI, 2009). The goal was to obtain target strength of 35 MPa at 28 days considering a slump value of 75–100 mm. Before the test all aggregates were taken to SSD condition. Cements and aggregates content kept same for all mixes while water was varied to obtain target slump value.The detailed concrete mix proportions of constituent materials, metallic and non-metallic fiber used for the study are given below in Table 1.

Table 1: Mix proportions of the concretes used in experimental work

Mix	Water (Kg/m3)	Cement (Kg/m3)	Coarse aggregate (Kg/m3) [SSD (OD)]	Fine aggregate (Kg/m3) [SSD(OD)]	Fiber (Kg/m3)
Pc (0%)	205	539.5	999 (992)	601 (594)	0.0
J1(0.1%, 25mm)	206	539.5	999 (992)	601 (594)	0.2345
J1(0.2%, 25mm)	208	539.5	999 (992)	601 (594)	0.4690
J1(0.3%, 25mm)	212	539.5	999 (992)	601 (594)	0.7035
G1(1%, 40mm)	211	539.5	999 (992)	601 (594)	2.345
G2(1.5%, 40mm)	214	539.5	999 (992)	601 (594)	3.5175
G3(2%, 40mm)	217	539.5	999 (992)	601 (594)	4.690

2.2 Concrete Mixing

Concrete was mixed using a machine mixer. Appropriate quantity of coarse aggregate, fine aggregates (SSD) and cement, were first dry mixed for a period of 2 minutes. The mixing water was then added to the mixer. Fibers were dispersed by hand in the mixture to achieve a uniform distribution throughout the concrete, which was mixed for a total of 4 min. After mixing, the workability of concrete was determined using slump cone. The concrete was placed in the fabricated mould and tamping is done using a tamping rod. A smooth steel trowel was used to finish the fresh concrete.

2.3 Strength Testing

The strength of concrete was determined by casting 6-inchcube specimen. The specimens were tested by universal testing machine after 28 days curing. Load was applied gradually at the rate of 2mm/min till the specimens fails.

3. RESULTS & CONCLUSIONS

3.1 Compressive and Tensile Strength

The paper reported experimental results on using Metallic (GI) and Non-metallic (Jute) fibre in concrete with respect to the plain concrete.Concrete compressive and tensile strength data are given in Table

2.Relationship between the Jute fiber and GI fiber content with concrete compressive strength are shown in Figure 1.

Table 2: Strength characteristics of fiber reinforced concretes

Type of concrete	Compressive strength (MPa)	Tensile Strength (MPa)
Pc	36.5	2.13
J1	38.87	2.99
J2	39.62	3.20
J3	41.03	3.37
G1	39.92	3.62
G2	40.86	3.93
G3	42.35	4.03

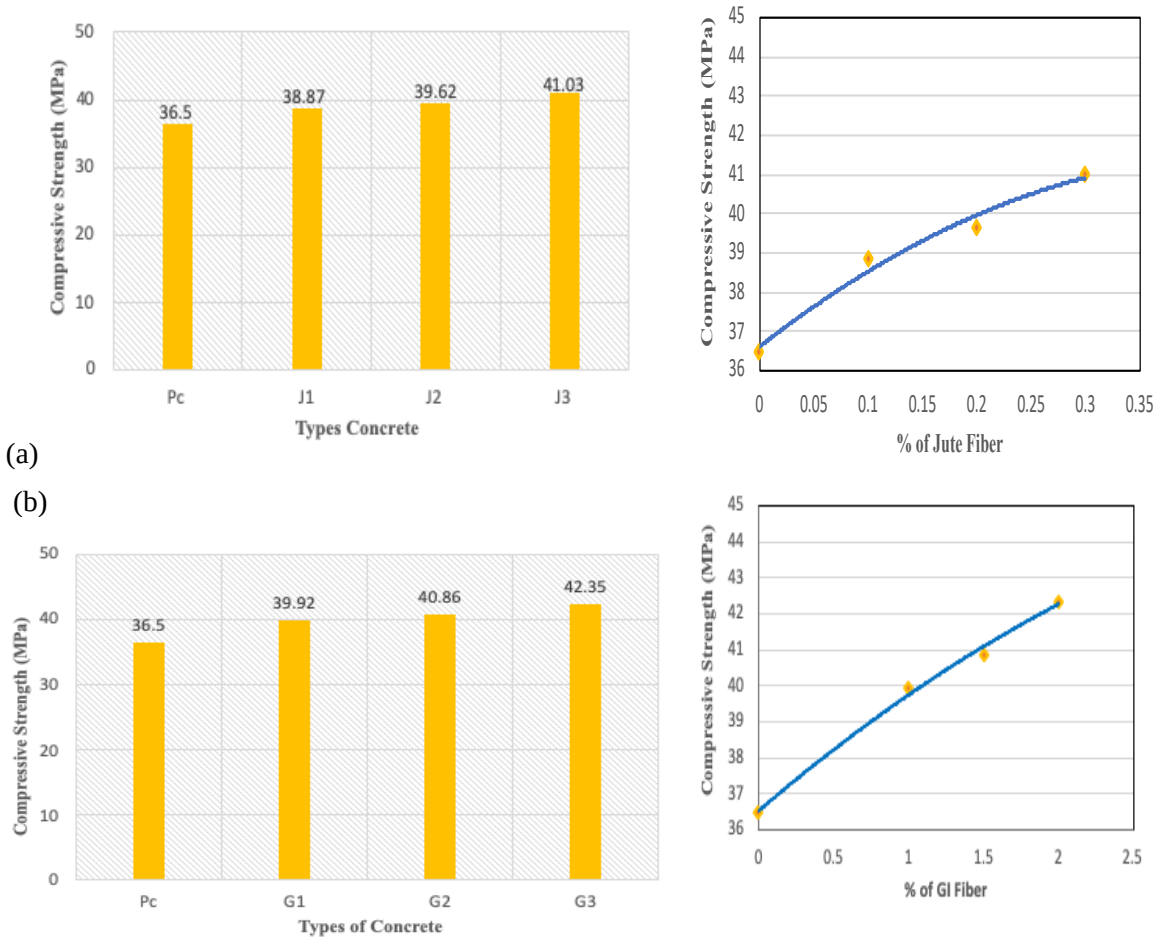

Figure1: Relationship between fiber content and compressive strength of (a) non-metallic fiber reinforced concrete; and(b) metallic fiber reinforced concrete

It is observed from the Figure 1 that with the increasing of fiber contents compressive strength of concrete also aincreased for both cases. This is because interlocking effect of concrete matrix increased and better bond achieved between fibers and concrete.With the addition of 0.1%,0.2% and 0.3% jute fiber (non-metallic fiber) the compressive strength of concrete was increased respectively 6.5%,8.0% and 12.5% in contrast to GI fiber while the compressive strength of concrete increased 9.4%,12% and 16% by adding 1%,1.5% and 2% Galvanized steel (Metallic fiber) respectively. A maximum of 12.5% increment in compressive strength (with respect to the control concrete) was noted with addition of

0.3% volume of jute fibers (J3) in the concrete (Fig.1a).on the other hand, addition of 2% GI fibers (G3) maximum compressive strength of 16% was found (Fig.1b). Relationship between the Jute fiber and GI fiber content with concretesplit tensile strength are shown in Figure 2.

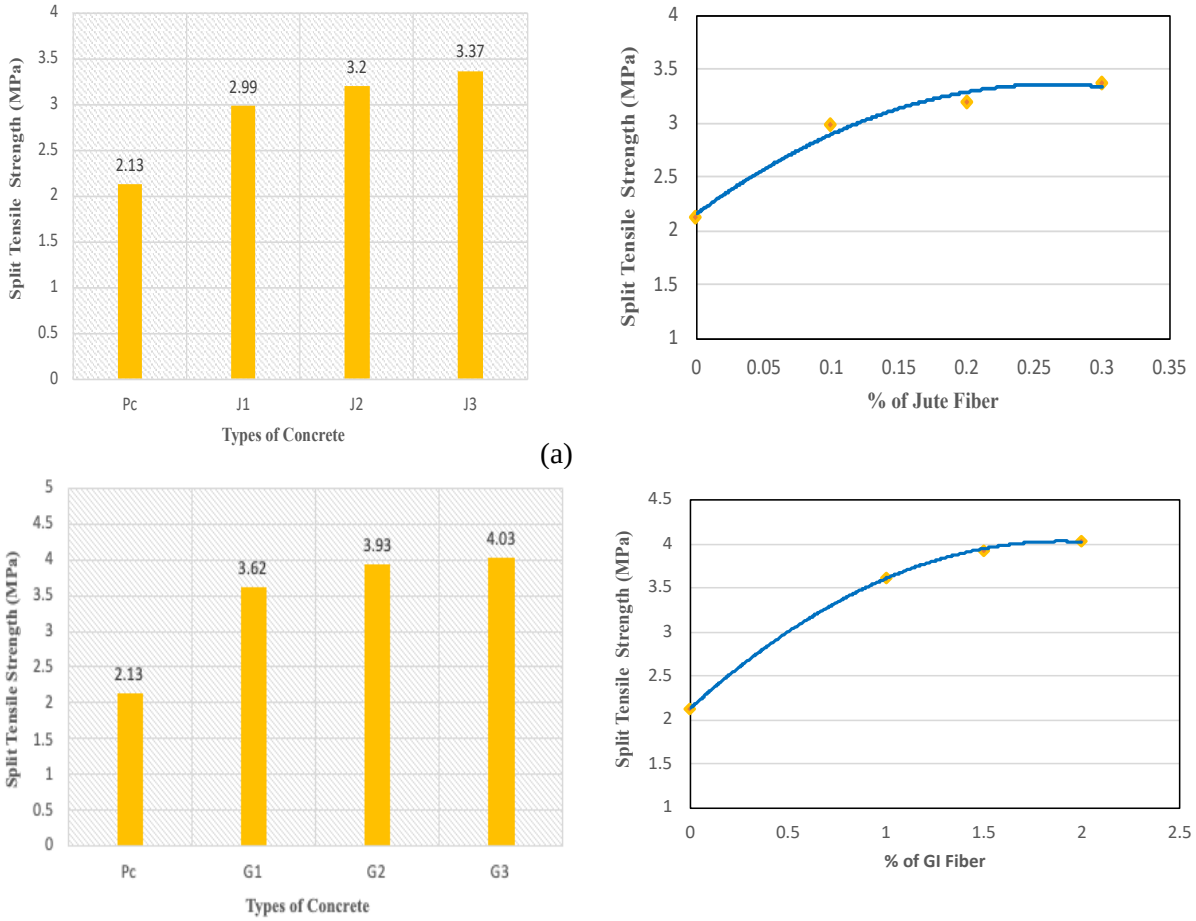

Figure2: Relationship between fiber content and split tensile strength of (a) non-metallic fiber reinforced concrete; and(b) metallic fiber reinforced concrete

From Figure 2, it is stated that the tensile strength was improved with addition of small quantity of fibers.The tensile strength increased respectively 40.4%,50.2% and 58.2% with the addition of jute fibers by volume fraction compared to the plain concrete while the increment of tensile strength was observed 70%,84.5% and 89.2% by adding GI fibers in concrete compared to plain concrete. The role of crack bridging ability of fibers and interfacial adhesion mainly prevented the concrete from splitting. Best result achieved for 2% GI fiber addition and approximately 89% increase in the split tensile strength was noted, while this was approximately 58% for 0.3% Jute fiber addition. The crack-bridging capacity of the fibres mainly prevented from the splitting of concrete.

4. CONCLUSIONS

The paper reported experimental results on using metallic (GI) and non-metallic (Jute) fibre in concrete with respect to the plain concrete. The following conclusions can be drawn from the above experimental results:

- With the addition of jute fiber (non-metallic fiber) the compressive strength increases from 6.5% - 12.5% with respect to plain concrete.

- The compressive strength of metallic fiber (GI fiber) reinforced concrete increased from 9.4% -16% with respect to plain concrete.
- The fiber content of mamimum compressive strength was found in case of 2% addition of GI fiber in concrete.
- The tensile strength increases by 40.4% - 58.2% compared to the plain concrete with the addition of jute fiber in concrete.
- By adding GI fiber in concrete significant increment of tensile strength 70% - 89.2% was found compared to the plain concrete.
- The highest enhancement of tensile strength was found in case of 2% addition of GI fiber in concrete.

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